45| Претходно саопштење
*Preliminary report*
doi 10.7251/STP1813616S ISSN 2566-4484

# ECOLOGICAL ASPECTS OF SNOW AND ICE CONTROL ON ROADS

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***Abstract:***

In all countries where, with regard to climatic conditions, the occurrence of ice on the roads is possible, great efforts are made to minimize the loss of friction on the pavement surface, thereby ensuring continuity and safety of traffic and minimizing human casualties and material losses. Modern road maintenance in the winter period is based on finding a solution to reduce the freezing point of water by creating chemical solutions and breaking the bond between ice and pavement. However, the use of various chemicals and abrasive materials, especially in uncontrolled quantities, can have serious environmental consequences. This paper presents the most commonly used materials for preventing ice, as well as underlines negative impacts and recommendations for mitigation of environmental threats.

*Keywords: snow, ice, control, environment*

# EKOLOŠKI ASPEKTI KONTROLE SNEGA I LEDA NA PUTEVIMA

***Rezime:***

U svim zemljama gde je, s obzirom na klimatske uslove, moguća pojava poledice na putevima ulažu se veliki napori da se gubitak trenja na kolovoznoj površini svede na minimum i na taj način omogući kontinuitet i bezbednost saobraćaja, a ljudske žrtve i materijalni gubici svedu na minimum. Moderno održavanje puteva u zimskom periodu se zasniva na pronalaženju rešenja kojim bi se snizila tačka mržnjenja vode putem stvaranja hemijskih rastvora i razaranja veze led-kolovoz. Međutim, primena različitih hemijskih supstanci i abrazivnih materijala, posebno u nekontrolisanim količinama, može imati ozbiljne posledice po životnu sredinu. U radu će biti prikazane najčešće upotrebljavane materije za sprečavanje poledice, te naglašeni negativni uticaji i preporuke za manje ugrožavanje životne sredine.

*Keywords: snow, ice, control, environment*

# 1. INTRODUCTION

In all countries where, with regard to climatic conditions, the occurrence of ice on the roads is possible, great efforts are made to minimize the slipperiness of pavement surface, thereby ensuring continuity and safety of traffic and minimizing human casualties and material losses. The number of traffic accidents due to the loss of friction at the contact point between the wheel and the carriageway in the world is very high, and in the region this problem is very highlighted.

Qualified road, safe in all weather conditions is of big importance, not only for the inhabitants, but for the society in general. Today, life could not be imagined without passable road communications during the winter, in narrow geographic area as well as at the international level.

Excessive amount of spreading material that roughens the pavement, or chemicals used to melt snow and ice is not generally acceptable for environmental and cost impacts, yet, in the other hand, in principle it is not acceptable to overcompensate the speed of driving in such disadvantageous conditions due to waste of time and higher fuel consumption.

Today is undoubtful that the only way to preserve the roads with heavy traffic without snow and ice is to use the dissolving agents. Such a way of maintenance is the only one, in general, that ensures unhindered driving in winter conditions.

However, there is still a great deal of safety responsibility on drivers' side as well, since it is necessary to be ready for surprises in changing conditions on winter roads. First of all, it is necessary to change the driving mode and this is much easier to do than to change the condition of the pavement.

# 2. ICE

## 2.1. PRINCIPLES OF ICE FORMATION

Ice represents a solid aggregate state of water, which is reached at temperatures equal to or less than 0°C (point of frost). Due to the specific spatial distribution of the molecules of water at that time, the ice has a lower density of water (for about 8.5%) and floats on its surface. When frozen, the volume of water increases for about 11% [1].

Specific temperature of ice is twice lower than water in liquid condition. Because of this, ice is relatively quickly formed on the surface of the water cooled down to a temperature of 0°C, and for its melting it takes a much smaller amount of heat than for evaporation of liquid water. Increasing salinity reduces the point of water freezing.

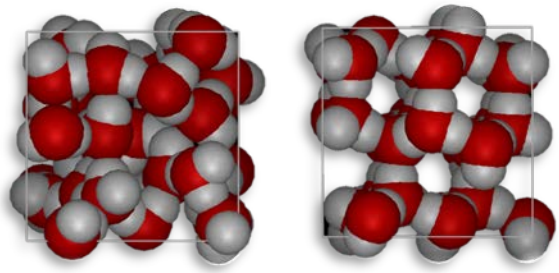

*Figure 1. The volume of water (left) and ice (right) [2]*

In ice, each oxygen atom has four neighbouring hydrogen atoms - two from its own molecule, and two from closest molecules (Figure 1). This structure is not the most dense possible packaging of water molecules. As the temperature rises, melting of the ice and the weakening of hydrogen bonds occur. This results in a density increase which is at the maximum at 4°C [3].

### 2.2. ICE ON THE PAVEMENT

Ice on the pavement occurs in the form of black ice. This is the occurrence of smoothness of the pavement with reduced adhesion, which is influenced by weather conditions. The black ice is formed by freezing of water and moist on the pavement. Given the type of formation, the following forms are distinguished [4]:

- Compacted snow is a black ice that occurs when snow sticks to the pavement and by stepping on and freezing of compacted snow due to driving vehicles or by freezing the snowy slush or the remains of snow;
- Snow frost occur due to freezing of moisture from the air on the pavement;
- Black ice is homogenous layer of ice, formed on pavement due to freezing rain precipitation on the cold pavement. Super frosty water drops automatically turn to ice, with additional freezing of water due to snow melting, as well as other water that appears at the pavement (from access roads, berms, slopes and gutters).

## 3. LOWERING THE WATER FREEZING POINT

Modern winter road maintenance is based on finding a solution for lowering the water freezing point, creating chemical solutions, decomposing the Na-Cl bonds, as well as ice-pavement bond all of which should be achieved in a "smart" way.

Salt is a universal agent for lowering the freezing point. That is only a shorter form of the expression “agent for lowering the water freezing point to the temperature lower than 0°C”. In the field of winter maintenance, a substance that postpones forming of ice is a very useful and good thing.

There are many alternative chemicals that can be used to lower the water-freezing point, but the salt is still the best solution because it costs much less than other alternatives, is easier to handle and is very reliable in achieving safe driving conditions.

The snow accumulates on road and becomes compacted due to traffic. Then it begins to bond with the pavement causing the problem because of the impossibility of removing it with mechanical means. The only way to break the ice-pavement bond is by using chemical means, such as road salt.

During the action of ice removal, it is applied at the top of the compacted snow. If there is a sufficient amount of moisture and heat, which most commonly occurs as a result of a combination of sun, traffic and higher daily temperatures, the road salt will dissolve and form a solution. The graines of salt that turn into the solution will penetrate through the compacted snow towards the pavement surface, by providing the melting along the entire path. As far as the melting conditions are concerned, the heavier crystals of salt must exist, powerful enough to perform melting all the way till the road surface. Penetration depth of salt solution (salty water) depends on the density.

The amount of time needed for salt to get into the solution and start melting snow or ice is determined by the temperature and humidity, and the total amount of the salt solution used must be spread over the surface of the road by transverse fall or through movement

of traffic. Change of pavement temperature will accelerate or slow down the chemical reaction. The characteristics of the salt used also influence the reaction time and the melting effect [4]. The road salt is effective up to -21°C, but its application is not recommended below -10°C. Effect of salt on melting of water can be assessed on the basis of data given in Table 1.

*Table 1. Kilograms of ice melted by 1 kg of salt [4]*

| temperature [°C] | one kilogram of NaCl melts |
|---|---|
| -1 | 46.3 kg of ice |
| -4 | 14.4 kg of ice |
| -6.7 | 8.6 kg of ice |
| -9.4 | 6.3 kg of ice |
| -12 | 4.9 kg of ice |
| -15 | 4.1 kg of ice |
| -18 | 3.7 kg of ice |
| -21 | 3.2 kg of ice |

With a decrease of the pavement surface temperature, a higher salt concentration is needed to prevent freezing. However, as snow and ice melt and dilute the salt solution, the freezing point of the solution increases, and freezing is possible.

Depending on the local conditions and the policy, the scope of application of road salt may vary between 80 and 600 kg/km at the two lane road.

## 4. SUPPLEMENTS AND ADDITION TO THE ROAD SALT

Depending on the climate characteristics of the area, quantity of salt to be applied is determined. However, regardless the quantity of salt used in a particular region, it can probably be used less in a more efficient way, i.e. with more accurate selection of procedures depending on the conditions.

The best way to optimize the quantity of road salt used is replacement or addition of other chemicals. Five most frequently used chemicals for removal and prevention of ice forming are three “road salts” and two “alternatives”. Some other chemicals used have a high harmful effect on the environment (urea), can be toxic to humans and the animal world if swallowed (glycols), volatile, flammable and toxic (methanol) or have not been sufficiently tested to reliably determine the safety and usefulness of their application (sodium formate) [5].

### 4.1. CALCIUM CHLORIDE (CaCl2): VERSATILE AND EXOTERMIC

One of the advantages of calcium chloride (Figure 2) is that it reacts at lower temperature than others. It is exgotermic, it absorbs moisture from atmosphere and releases heat when it passes into the liquid state. It can prevent freezing of the pavement and provide moist required for the salt to transform to a solution.

It takes effect at a temperature of -15°C or lower, which means that it is superior to salt for a few degrees. It can be used as previously moistened agent while mixing with sand to avoid freezing. It can also work well in combination with salt.

It is naturally liquid, but it can also be found in solid state, in the form of grains or small plates. Since it draws moisture from the air, it is an advantage in certain conditions and can improve the ways of managing traffic problems during the humid conditions, but it can slow down the process of reaching the clean roadway after the snowfall.

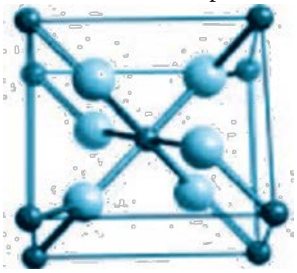

*Figure 2. Molecular mesh of calcium chloride [4]*

It is also an effective anti-dust agent on gravel roads during the summer.

### 4.2. MAGNESIUM CHLORIDE (MgCl2): ROAD ANTIFREEZE

Magnesium chloride (Figure 3) originates from the Great Salt Lake, in the state of Utah in the United States of America. It represents a hygroscopic substance, takes and retains moisture regardless of the origin of the same (from air, from carriage, snow, ice). Prevents bonding of snow for the pavement and prevents forming of glaze and black ice.

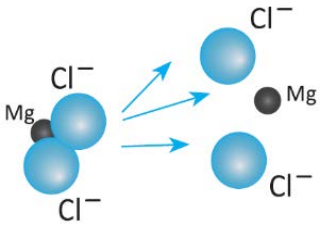


*Figure 3. Composition of magnesium chloride molecules [4]*

It is used by spraying in liquid state on the roads before snowfall; its eutectic point is -36.6°C. It acts as anti-freeze for roads, lowers the temperature of water freezing and prevents the appearance of ice that creates a strong bond to the road. When used, the road cannot become slippery, security is improved, and the number of accidents is reduced.

It prevents the appearance of black ice and is also used in case of rain that turns to ice. If used as a sand moisturizing agent, it affects the better bonding of the abrasive to the compacted snow.

Magnesium chloride is one of the rare chemicals which can gradually destroy concrete. Some tests showed that with proper application there are no negative effects for ground and surface water or vegetation.

### 4.3. CALCIUM MAGNESIUM ACETATE (CMA): VINEGAR AND OAT FLOUR

As a chemical compound (Figure 4), calcium magnesium acetate (CMA) is a dolomite limestone rock and acetic acid. For 25 years it is applied as an agent for the control of snow and ice on the roads. It can be used in a liquid form or combined with salt and sand. To prevent the formation of ice, it is used as a liquid.

CMA does not melt snow and ice, but turns it into oat-flour texture. This allows easy cleaning and removal, and if road traffic is very intense, it has the tendency to remove the slush aside very efficiently. However, in that case it must be applied at the beginning of snowfall prior to the accumulation of large amounts of snow, because it is more effective in preventing the formation of ice than in eliminating the already formed ice.

*Figure 4. Molecular grid of calcium magnesium acetate [4]*

It prevents the transformation of the compacted snow into ice and its subsequent bonding to the pavement, but once ice is created, another chemical should be used to break the bond.

Over 30 years of testing and use showed that it has no impact on the soil because it is biodegradable. It has very little mobility, does not penetrate the soil deeply, so it can not reach the groundwater. It smells like vinegar and therefore is not as attractive to animals as the salt. In Scandinavia it is used in the areas where there are many deer, in order to prevent traffic accidents involving vehicles and animals.

It is less corrosive for metal than salt. It does not contribute to the grinding and peeling of new reinforced concrete.

### 4.4. POTASSIUM ACETATE: SMALL BIOLOGICAL OXYGEN DEMAND

Potassium acetate (Figure 5) was created by reaction of acetic acid and potassium carbonate. Previously, it was primarily used as an agent for removing ice, but also for keeping the railway track switches open, preventing the icing of lids on the manholes, even as a water antifreeze in the toilets.

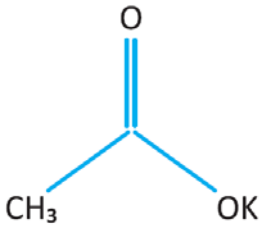


*Figure 5. Chemical structure of potassium acetate [4]*

It is applied at the extremely low temperatures. If applied at the beginning of snowfall it can prevent the formation of ice-pavement bond. As an additional advantage, it is underlined that it leaves sediments on roads, which is important in preventing the formation of ice during the next snowfall, so that it can be considered to have a prolonged effect.

It is biodegradable - it degrades to potassium and acetate. As it changes to carbon and water, it needs an insignificant amount of oxygen. This process is called “biological oxygen demand”. It has been found that it is toxic to fish in growing concentrations.
It is considered to be non-corrosive, but it must not come into contact with galvanized metals.
Must be stored in clean and sealed container. Otherwise, it could start biodegradation prematurely and expose itself to biological growth.

### 4.5. SODIUM CHLORIDE (NaCl): OLD, GOOD SALT

Sodium chloride (NaCl) (Figure 6) is natural product. It can be hundreds of millions of years old, or it can be just created a year ago in a solar salt basin. Road companies have been applying it for over 60 years. It is the most studied and the most comprehensible of all chemicals used to eliminate ice.

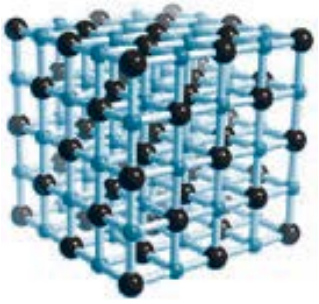

*Figure 6. Molecular grid of sodium chloride [4]*

Most snow and ice occurrences take place in the range of temperatures where sodium chloride has the best effect, i.e. above -9°C. At this temperature there are no significant differences in the effects of all the chemicals described. They all work equally fast.
Since most of snowfalls is accompanied by a decrease of temperature, modern practice of preventing formation of ice, which assumes application of means for direct removal of ice, prior to or in early phase of the snowfall, makes NaCl a very attractive alternative.
When the temperature is too low to be used alone, it has excellent effect when previously moistened with some of better ice removing agents. It is far cheaper to use a previously moistened NaCl than using only some of the more expensive alternatives.
Temperature of the pavement surface is probably the most significant variable, and NaCl lowers it. This effect is less than 1°C and the duration is 5 minutes or less, after which the effect disappears. Some other agents increase the temperature of the pavement, but this effect also disappears very quickly.
To start acting, it needs moisture from snowfalls. Therefore, it is increasingly used as a pre-moistened or as a salt solution, so it shows the effect immediately. However, after the end of the rainfall, it helps to dry the road surface by returning it to a state of safe conditions. Unlike that, some hygroscopic agents continue to take moisture retaining in that way moist conditions on the road.
It can be purchased in liquid form, or it is possible to make a solution at the construction site, which is much cheaper. Its great advantage is that it is much cheaper than other agents, but it is not a good solution for extremely low temperatures.

## 5. ENVIRONMENTAL IMPACTS

Melting agents cause damage to the road, buildings, vehicles and road surrounding area. Some of the examples of negative effects include:

- corrosion of vehicles and reinforcement at the facilities and in buildings with bad or damaged anti-corrosion protection;
- damage to the vegetation due to contact in direct vicinity of the road (Figure 7);
- damage to the vegetation and parts of vegetation as consequence of receiving excessive quantities of sodium chloride materials from the soil;
- damage to the fish due to short-term saturation of water with chlorides after the rain.

*Figure 7. Damage to plants along the road due to the use of salt [6]*

Reducing the spread rate, especially with the use of wet salts, improved spreading technology and enhanced protection measures, can provide less damage to the road environment. In the cases where salt continues to be a problem, there are several precautions that can be taken to avoid negative effects on vegetation, and as a result of collecting droplets of salt for defrosting on leaves and branches.

Planning and designing roads should avoid areas with vulnerable vegetation and agricultural crops. The salt should be used in an optimal amount to prevent ice-bonding for the pavement, and the electronic controllers should be used to control the regulation of quantity. Also, modern road meteorology should be used to obtain reliable weather information and apply salt only when necessary. In hazardous areas, it is necessary to apply known techniques of snow cover control to minimize the amount of snow on the roads, which will also reduce the need for salt.

As for planting, the plants resistant to salt should be considered in zones subject to spreading salt. Vegetation is planted in groups for maximum protection, and in line with the existing vegetation at the terrain. Vulnerable species should not be planted within the boundaries of spreading salt and in the vicinity of streamflow collection zones, such as depressions. If this has to be done to fit into the existing road environment, the planting

should be done at places that are elevated compared to the surface of the pavement or in the areas physically protected from salt. In order to protect the vegetation from the solutions saturated with salt, it is necessary to pay sufficient attention to the design of the drainage system, as well as to its regular maintenance.

For long-term survival of vegetation in urban zones, newly planted softwoods should be protected by raising the coating from coarse cloth during the winter months, the use of agents that prevent drying and evaporation at weak offshoots of vulnerable plants, protect naturally formed/regulated zones from salt spraying by planting salt resistant species as a buffer. Where feasible and cost-effective, it is necessary to consider the use of snow fences to prevent snow accumulation on the roads or to collect dispersed salt to prevent further spreading.

As for the trees next to the road, the aggressive effect of spreading agents is best tolerated by wild chestnut, blue spruce, Austrian pine, hops, white oak, red oak, black carob, etc. More sensitive species are amur maple, Manitoba maple, yellow birch, paper birch, white ash, black cherry, etc. The following sensitive trees should be avoided next to the road: fragrant dishes, red maple, sweet maple, silver maple, black walnut, red pine, white pine.

If the field and nutrient crops are planted near the road, then it should be high or thin wheat grass, because they are the most resistant. Wheat, barley, oats, alfalfa and sweet cloves can be planted as well. The most vulnerable are soy, white beans and red clover.

Spreading material for roughening has no chemical effect on the road and its environment, but can be spread by the traffic over the edge of the road to nearer areas. This causes the following effects:

- clogging of drainage devices;
- pollution of surfaces that can be used for farming;
- pollution of green surfaces and rise of berms;
- damage to parked vehicles and driving vehicles;
- creating dust.

Ecological consequences of usage of large quantities of abrasives are often considered as higher than consequences from using salt. Some regions have completely switched to the use of salt to avoid accumulation of sand in collecting basins and sewage systems [7].

Among the other ecological issues caused by abrasive means are damage to the vegetation along the roads and their accumulation in watercourses, basins and lakes.

If one considers the financial aspect, it can be said that the ton of salt is about five times more expensive than the ton of stone material for spreading, but for the same surface it takes five to ten times more stone material than salt.

Ecologists believe that stone material mixed with oil, mud and dirt (accompanying elements of the road) represents a significant environmental burden. If the increased use of salt is analysed from the aspect of road safety, experts have concluded that stone material is equally dangerous during the rain as black ice.

## 6. NEW TECHNOLOGIES AND ALTERNATIVE MATERIALS

New materials and technologies enable achievement of significant improvements in many fields of science. Also, by using some of the modern elements of the road and road equipment, it is possible to have a significant influence on the improvement of traffic conditions, as well as to increase the level of traffic safety. Application of new materials,

elements and equipment, besides all the advantages and time and money saving features, contributes to increase of environment protection.
In order to gain an efficient and economical system that reduces the risk and allows traffic to take place on all key road directions within the road network, it is necessary to establish a quality system of winter road maintenance.
In developed countries, a complete system for preventing the formation of black ice on the surface of the pavement has been developed. The core of this system is the network of Road Weather Stations (RWS). Using the probes in the pavement, these cells measure the temperature condition of the pavement surface and together with the meteorological sensors determine the parameters of the local microclimate. These data are then processed in a computer center.
RWS also enables automatic control of certain alarm systems depending on road conditions. Based on the data processed and the given parameters, the system notifies the winter maintenance service about the need for intervention, but the intervention of mobile teams is often endangered by the conditions of traffic and possible traffic jams on the road.

### 6.1. FIXED AUTOMATED SPRAY TECHNOLOGY

Fixed Automated Spray Technology (FAST) systems (Figure 8) are automatically controlled by ice early warning systems and they spray the road surface with a chemical solution before ice can form. During snowfalls, this prevents the accretion of snow in a compact layer on the road surface; the snow remains sufficiently soft for removal during standard winter maintenance operations. The de-icing agent is sprayed in a uniform manner onto the road surface using spray nozzles at the side of the road, spray discs in the road surface or by means of the innovative Micro-FAST technology [8].
The automated sprayer has a reaction at the optimum moment, a significant precision of spreading and use of the agent, including reduced adverse effects on the structure, which prolongs the lifespan of the structure and allows the use of various types of defrosting agents in the appropriate amount, which also affects the road environment.

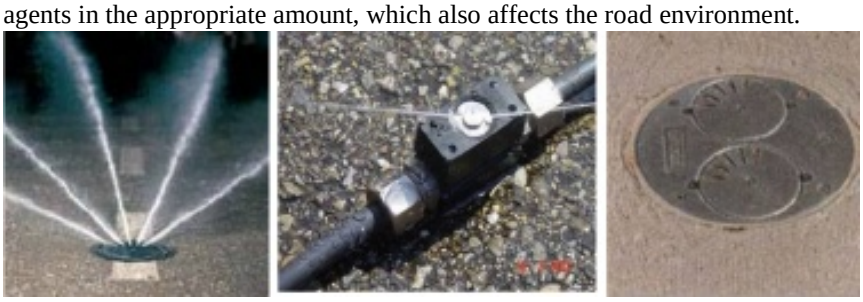

*Figure 8. Automated spray technology systems [8]*

### 6.2. SOLAR SYSTEMS

The future of winter pavement maintenance and preventing the formation of ice on them are the solar roads. Their profitability is high, as cities could have a significant reduction in the cost of removing snow off the pavement, and pollution problems caused due to the use of chemicals (CaCl2, NaCl, etc.) could disappear.
It is also estimated that the number of accidents caused by black ice will be reduced. This method of road maintenance is already being applied successfully in Toddington (England), as well as at the Hiroshima Airport (Japan) [9, 10].

The solar system (Figure 9) compiles two solar collectors that are integrated into the surface of the pavement (presented in orange) and two thermal storages (presented in blue). The energy collected in this way during the summer is stored in thermal "banks" and it directs to defrosting of the pavement during the winter when the pavement temperature drops below 0°C.

The successful demonstration of this project in Toddington was carried out by the United Kingdom Highway Agency in cooperation with the Road Research Laboratory. The system is designed in such a way that heat, accumulated in pipes beneath the carriageway, is activated when necessary, defrosts the pavement and thus creates adequate conditions for unhindered traffic without danger of black ice.

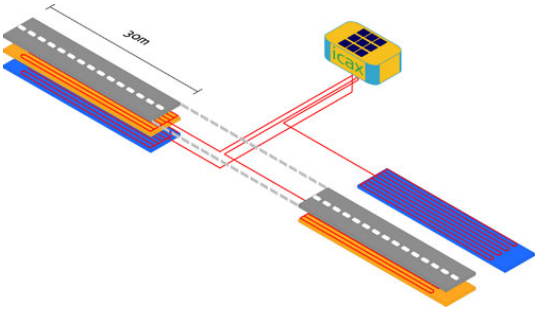


*Figure 9. Solar systems on roads [9]*

An inter-seasonal heat transformer can be used to remove snow and ice from the pavement, public squares, parking and airports. In this way, accidents are prevented and life is preserved, but also, the durability of the pavement is prolonged, as its heat is controlled during the summer and winter. It reduces the consumption of salt and its adverse environmental impact, and therefore reduces the cost of road maintenance and repairing of maintenance machines. Favourable effects related to the level of service on the roads reflect in the reduction of crowds and traffic jams, and the time for possible road repair is prolonged [10].

Another very successful example of using solar energy for maintenance of traffic surfaces was used in Japan at Hiroshima Airport (Figure 10). The aforementioned defrosting system prevents the formation of ice on the landing and take-off field, runways, taxiways, and aprons. Costs and time required for maintenance of chemical spreading machines are reduced, and thus the life of the traffic surfaces at the airport is prolonged.

*Figure 10. Application of solar systems at the airports [9]*

The system allows unhindered traffic to be carried out at the airport without the discharge of harmful substances into the environment. After determining the outside temperature, it is self-activated to prevent ice forming.

### 6.3. HEATING PANELS

One of the innovative technologies of snow and ice control is installation of heating panels (Figure 11), mostly used on bridges. According to the report of the Federal Highway Agency in the United States of America, three heating technologies are usually used: hydraulic, thermal and electrical [11]. In a hydraulic heating system, the heated liquid is pumped through a pipe mounted in the plate. In the heat pipe system, the operating fluid contained in the steel pipes is evaporated and condensed due to passive heat transfer. In an electric heating system, heat is generated by electric resistant cables placed in the plate near the surface [12].

According to Conger [13], the operating costs of the heat pipe system are lower than the electrical or hydraulic systems. The report on the use of heating panels concludes that the available technologies for pavement heating do not represent any problem for the structure and no adverse effect on durability of bridge was observed. The NCHRP report concluded that the technology of the heating panels is feasible, that it does not pose a problem in the construction and that there is no adverse effect on the load capacity of the bridge. However, it is indicated that the error of one sensor may cause the whole system to malfunction and that selection of the proper working fluid for the heat of the pipe is important [13].

*Figure 11. Heating panels [14, 15]*

### 6.4. ALTERNATIVE SOLUTIONS

If considerations include high costs and problems caused by traffic accidents almost on a daily basis (especially during the winter period), it is justified to use new materials and technologies during the process of planning, design, reconstruction and maintenance, as well as the introduction of a system for monitoring and analysing traffic. Therefore, special

attention should be paid to the application of new materials and technologies, as their application has multiple effects on maintenance savings, safety and traffic flow.

NaCl is effective, but its use causes corrosion of reinforcement, corrosive damage to cars and soil contamination due to increased NaCl concentration along the road, as well as in the waters. In the last few years there has been a lack of this material, causing the increased costs and renewed interest in alternative materials that can be used to defrost the pavement.

In an effort to increase the efficiency of the removal of ice from the pavement and reduce the corrosive effect of NaCl, new alternative solutions have been developed, which differ in their mode of operation, operate under different conditions and have a different impact on human health and the environment [3].

Some of these materials are:

- CG-90 (so called surface saviour) [16] - Resistant to the corrosion, used in the form of sprayer and has wide application. It is applied directly on ice and acts 1.5 times faster than sodium chloride. The advantage is that it prevents damage to the road surface, and it has better effect against corrosion both from NaCl and CaCl2. The only danger is possible dissolution over time into its components - chloride, salt and magnesium that can cause corrosion. A small amount of phosphorus in salt acts as a stimulant for plant growth. As it represents a type of salt, it is necessary to take care of the protection in order to avoid skin irritation;
- CMS-B, also known as MoTech, is a sugar beet processing product whose defrost properties have been recently discovered and are still in the testing phase. Sugar beets are used to produce sugar, giving various by-products. Water from sugar beet is separated during the processing process for obtaining different compounds. Of the processing residues, 10% make NaCl in the solution itself. It has been noticed that it has positive effect as defrost agent up to -23°C. It is used as spray, and it is added to the sand with whom it gives good results.

Experiments on environmental impact have not been made since basic substance is NaCl, so the effects are the same as well. As far as the man is concerned, NaCl irritates the eyes, skin and can create abdominal disturbances. Protective clothing and gloves are recommended. It is very slowly decomposed at temperatures below zero.

In the domain of the research of the defrosting agents, products that originate from by-products from agricultural raw materials, including corn, wheat and rice, also draw considerable attention. There is currently little information about the production process, since most of the manufactured materials are owned by producers - farmers or processors. Some of the existing agricultural products that can be used for defrosting are: mono-acrylic esters, processed agricultural by-products, wet grinding maize, beer by-products, plant material particles, monovalent and polyvalent alcohols, reduced sugar, various types of salts, etc. [3].

Their use is being tested in laboratories, test and evaluations are performed, and recommendations are defined, but mostly remaining at that level. Many of these products are biodegradable, and therefore they represent minimal concern for vegetation, for human and animal health compared to other types of defrosting agents. Moreover, small concentrations of phosphorus and ammonia in organic lubricants can provide nutrients for faster plant growth.

Research in the world has led to the selection of several alternative defrost agents based on agricultural raw materials, whose further development, i.e. use, makes sense.

The selection is made taking into account: the likelihood of defrosting, usability, possible effects on the environmental resistance, the anticipated price and availability, the damage caused to the vehicle, the possible effects on the environment.

Comparison was made with respect to NaCl whose effect is well known. By combining any of these substances with NaCl it is possible to achieve the same or better effect than it can achieve itself, and less pollution of the environment.

Geomelt 55 (formerly known as ICE BITE 55) [17] is an anti-icing fluid, a natural, agricultural product, obtained from renewable sources of sugar beet and has proven to have ice control performances, the same or slightly better than traditional solutions. It is suitable for use in environments where the impact on environment is important. It is a product of molasses (high fructose corn syrup) (Figure 12).

*Figure 12. Molasses [18]*

Also, two types of biofuel were approved for further laboratory testings. Their commercial names are BioOil and E310, and they have not been examined as defrosting agents before.

BioOil is derived from the conversion of biomass in Canada, dark brown, liquid, with the same odour as plants it was derived from. It was created in the process of pyrolysis where biomass, such as forest residues (bark, sawdust, shavings, etc.) and agricultural residues (sugar cane, waste in its processing, wheat straw, etc.), is exposed to a temperature of 400-500°C in the environment without oxygen. It is generally used as a fuel for a boiler.

E310 is obtained from corn in cereal processing plants. It is obtained in the process of converting corn into ethanol, where E310 appears as one version of this powder product.

Another type of agricultural product is glycerine. It is colourless, odourless, liquid, low toxicity, has great application in the pharmaceutical industry, personal care, food. Glycerine (molecular formula C3H5(OH)3) (Figure 13) has three hydroxyl groups that are responsible for solubility in water. It is a central component of many fats and lipids.

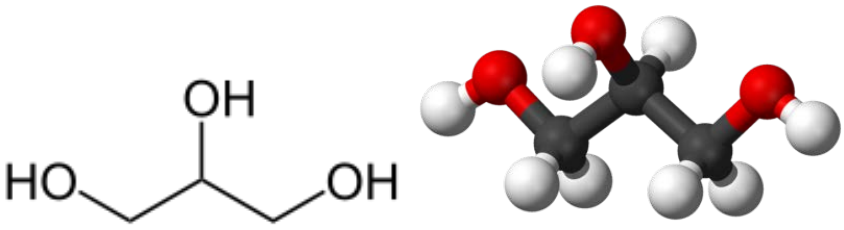


*Figure 13. Chemical structure and molecular grid of glycerine [19]*

Glycerine appears as a by-product during saponification of animal fats in treatment with sodium or potassium hydroxide in the production of soap. It is also obtained as a by-product in the production of biodiesel through the treatment of animal fats and various

vegetable oils with methanol in the presence of a catalyst of basic organic compounds in a process known as transesterification. Glycerine is very soluble in water. The minimum freezing point is about -37.8°C and it refers to the concentration of glycerine in the water of 60-70% [20].

By researching these products, their freezing points, the possibilities of defrosting, resistance and viscosity, the following conclusions were obtained. The ratio of 80% glycerine and 20% NaCl proved to be the best to defrost the roads [20]. When considering other factors, such as corrosion, dilution of NaCl reduces this effect, while the addition of glycerine does not increase the risk of corrosion. Impact of glycerine on vegetation is minimal.

The biggest concern when using this combination and its application is on the sidewalk due to its viscosity and possible effect on movement of pedestrians. Therefore, the ratio of 80% glycerine and 20% NaCl is accepted as the best because in this ratio the viscosity can be controlled in water.

In practice, it is used as a defrosting spray in various concentrations.

On the basis of the above, it can be concluded that in the future it is realistic to expect increasing use of defrost agents based on agricultural by-products. Further research is necessary in this field, but better results are certain and adverse environmental impact is minimized.

The most advanced and the boldest research related to the means for removing ice from the pavement today is taking place in the field of nanotechnology. Scientists are working on the development technology that would prevent the formation of ice on road [21].

A drop of water, when falling on the surface of pavement, splashes into millions of nanoparticles, then aiming to re-collect. During the course of this re-collection, the formation of ice occurs. If the success in acting on the particles at the time of the fall, when they begin to re-group and produce ice ia achieved, the formation of ice on the pavement would be completely prevented. For this purpose, “smart” nano-materials would be used to keep the particles at a “safe” distance.

Environmental damage would be reduced, the costs of the winter service would be reduced to a minimum, as well as the number of accidents on the road due to the frozen pavement. This possibility is still at the level of theoretical considerations and laboratory testing, but there is hope that in the not too distant future the idea will be put into practice.

## 7. CONCLUSION

Each year winters are getting stronger and removal of ice from the pavement demands more and more efforts and modern means. Control and removal of ice from the pavement is becoming one of the most important factors in winter road maintenance.

Currently, the best results in fighting against black ice are achieved by various types of salts, which have the widest application. The experience of the United States of America, as one of the countries with the most developed road traffic, according to numerous surveys conducted across the country, indicates the necessity for use of salt for winter road maintenance.

Nowadays, when the eco-awareness of the world population is growing, harmful effects of salt on the environment have been discovered. Many studies have been carried out in the hope that a suitable salt replacement will be found and will not have a harmful effect. Unfortunately, most of these studies ended with the conclusion that, for now, in the case

of large scale black ice, the only solution that gives quick and efficient results is the spreading of various types of salt on roads.
In addition to all the positive characteristics of spreading salts, scientists are trying to improve some alternative spreading materials and develop new methods that will eliminate ice in a faster and more efficient way. Their ecological justification and economic viability are also the aims that should be achieved.
New materials and methods will give better results, but the goal always remains the same, which is better functioning of traffic and reducing the number of accidents.

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